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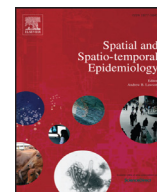
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Geographical variation in a fatal outcome of acute myocardial infarction and association with contact to a general practitioner

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ABSTRACT

Background: Geographical variation in incidence and mortality of acute myocardial infarction (AMI) is present in Denmark. We aimed at examining the association between contact to a general practitioner (GP) the year before AMI and a fatal outcome of AMI.

Methods: Register-based data and individual-level addresses including 69,608 individuals with AMI in 2006–2011. A Bayesian hierarchical logistic regression model was used to examine the association.

Results: A fatal outcome of AMI was seen among 12.0% (78%) of individuals with (without) contact to a GP the year before AMI. A significant association was estimated.

Conclusions: A fatal outcome of AMI was significantly associated with contact to a GP. A high population to GP ratio and long distance to GP could not explain the increased odds of a fatal outcome of AMI for individuals with no contact to a GP.

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1. Introduction

Cardiovascular disease (CVD) is a major cause of death in Denmark and worldwide (Murray et al., 2015). Acute myocardial infarction (AMI) is commonly referred to as a heart attack and is the most serious coronary heart disease. It is an acute disease as immediate medical treatment to restore coronary blood flow with either acute primary percutaneous coronary intervention (PCI) or initiation of antithrombotic pharmacotherapy and care in

dedicated coronary care units is needed to reduce heart damage and death. The incidence rate of AMI was 196 and 357 per 100,000 person-years in women and men in Denmark in 2011, respectively (Kock et al., 2014). The mortality rate of AMI was 52 and 71 per 100,000 person-years in women and men in Denmark in 2011, respectively (Kock et al., 2014). The incidence and mortality of CVD including AMI are continuously decreasing in Denmark and most industrialized countries (Koch et al., 2014; Murray et al., 2015; Beaglehole, 1999) due to increased focus on prevention and strategies to reduce risk factors. However, health varies geographically across and within countries (Jones and Moon, 1987; Howard et al., 2009; Lloyd-Jones et al., 2009; Shiue and Hristova, 2014; Rodrigues et al., 2015).

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In Denmark, spatial patterns in CVD have been shown at a regional level (Koch et al., 2014) and Kjærulff et al. demonstrated spatial clustering in AMI using individual-level data and small-area estimation methods (Kjærulff et al., 2016). Although many studies have focused on risk factors for CVD, there is a need to study geographical variation in CVD in order to identify new causal factors and thereby limit the geographical inequalities in CVD (Diez Roux, 2009).

Administrative register-based data covering the entire population provide an opportunity to analyze the geographical distribution of AMI without introducing selection bias, e.g. due to voluntary reporting or incomplete coverage of persons with different socio-economic positions. Furthermore, geographical analyses of individual-level data using information about location of residence can be performed using geostatistical methods based on point data. This limits the risk of ecological fallacy due to the modifiable areal unit problem as data are not aggregated in polygons using administrative boundaries (Openshaw and Taylor, 1979).

Geostatistical modeling and spatial analysis are often performed using Bayesian inference with Markov chain Monte Carlo (MCMC) simulations and Gaussian fields (GF). Until recently, analysis of a large number of residential locations was a computational burden when represented as a GF. The Stochastic Partial Differential Equation (SPDE) approach (Lindgren et al., 2011) transforms the continuously indexed GF to a Gaussian Markov random field (GMRF) by triangulation. The GMRF is discretely indexed and this provides a computational advantage compared to the GF as the GMRF is given by a sparse covariance matrix whereas the GF is given by a dense covariance matrix (Lindgren et al., 2011).

In Denmark, healthcare services are tax-financed and free of charge for all citizens. There are approximately 3600 general practitioners (GP) in Denmark. The GPs act as gatekeepers and are the first point of contact in relation to referral to specialists and to in- and out-of-hospital care. The GP plays an important role in primary and secondary prevention of CVD by preventive consultations, prescription of preventive treatments and rehabilitation. A total of 98% of Danes are listed as patient with a GP, the remaining 2% can consult any GP at any time by payment (Andersen et al., 2011; Pedersen et al., 2012). On average, Danes have about 7 GP contacts per year. A total of 15% have no contact to general practice within a year. Each GP was on average responsible for serving 1561 patients in 2008 (Lægeforeningen, 2013).

Studies have indicated inequalities in the geographical distribution of GPs and healthcare clinics (Gravelle & Sutton, 2001; Sanders et al., 2013). To our knowledge, the geographical distribution of GPs in Denmark and its association to CVD health outcomes has not previously been studied. The geographical distribution of GPs is an important issue because the availability of and proximity to GPs are important factors affecting access to primary healthcare. Carr-Hill et al. showed that living in urban areas and relatively near the GP were associated with higher rates of consultation in general practices (Carr-Hill et al., 1996). Studies have identified a number of factors (such as de-

pression, education level, living alone) affecting contact to a GP after an acute disease such as AMI (Nielsen et al., 2015; Ziegelstein et al., 2000).

The aims of this study were to: (1) examine the geographical distribution of a fatal outcome of AMI, and (2) estimate the association between a fatal outcome of AMI and contact to a GP the year before AMI using individual-level addresses and population registers in Denmark.

2. Material and methods

2.1. Register-based data and data linkage

All residents in Denmark (and in the other Nordic countries) have a unique personal identification number given at birth or immigration (Pedersen, 2011). The existence of the unique personal identification number enables individual-level linkage of data from different registers (and other data sources such as surveys) in a reliable manner (Thygesen & Ersbøll, 2014). Individual-level nationwide health-related registers have been established in Denmark providing data such as admission to hospitals (Danish National Patient Register) and cause of death (Danish Register of Causes of Death) (Helweg-Larsen, 2011; Lynge et al., 2011). Location of residence of all Danes (current and historic) is registered and geocoded (Christensen, 2011).

2.2. Study area and population

The study area consisted of Denmark with an area of 43,000 km². To evaluate the study objectives the risk of a fatal versus a non-fatal outcome of AMI was compared. Therefore, the study population only included individuals with an AMI (incident or prevalent) in the study period from 1 January, 2006 to 31 December, 2011. This was done as geographical variation in a fatal outcome of AMI in the general population (i.e. including individuals with no AMI) could be seen solely as a consequence of the geographically uneven distribution of AMI. A fatal AMI was defined by the underlying or contributory cause of death in the Danish Register of Causes of Death. A non-fatal AMI was defined by a primary or secondary diagnosis in the Danish National Patient Register. The World Health Organization's International Classification of Diseases, Tenth Revision (ICD-10) was used to identify AMI in both registers (ICD-10 code: I21). Only the first non-fatal AMI was included. An individual could experience first a non-fatal AMI and later a fatal AMI in the study period. The AMI was defined as fatal if a fatal AMI was experienced ≤ 28 days after the first non-fatal AMI (Madsen et al., 2003). If a fatal AMI was experienced >28 days after the first non-fatal AMI, AMI for this individual was defined as non-fatal.

The study population included 69,608 individuals with AMI of whom 17,196 had a fatal outcome of AMI according to the definition described above.

2.3. Characteristics of the study population

Information about address of residential location at date of AMI, date of birth, gender, migration and vital

Table 1a

Descriptive analysis of the study population by contact to a general practitioner (GP) the year before acute myocardial infarction (AMI) by means of number of individuals (N) and percentage (%) in Denmark 2006–2011.

Variable	Level	Contact to GP the year before AMI			
		Yes		No	
		N	(%)	N	(%)
Overall	–	56,236	(80.8)	13,372	(19.2)
Gender	Male	34,887	(80.7)	8340	(19.3)
	Female	21,349	(80.9)	5032	(19.1)
Age ^a (years)	30–49	4386	(83.3)	877	(16.7)
	50–59	7886	(82.6)	1660	(17.4)
	60–69	12,716	(82.3)	2237	(17.7)
	70–79	14,744	(83.2)	2952	(16.7)
	≥ 80	16,504	(76.2)	5146	(23.8)
Distance to nearest GP (km)	< 0.5	18,595	(80.6)	4490	(19.5)
	0.5–1.5	21,446	(80.6)	5156	(19.4)
	> 1.5	16,195	(81.3)	3726	(18.7)
Population to GP ratio ^b	< 1500	16,474	(80.7)	3935	(19.3)
	1500–2000	22,522	(80.8)	5345	(19.2)
	> 2000	17,240	(80.8)	4092	(19.2)

^a Age at AMI.

^b Population size per GP at municipality level.

Table 1b

Descriptive analysis of the study population by a fatal outcome of acute myocardial infarction (AMI) by means of number of individuals (N) and percentage (%) in Denmark 2006–2011.

Variable	Level	Fatal outcome of AMI			
		Yes		No	
		N	(%)	N	(%)
Overall	–	17,196	(24.7)	52,412	(75.3)
Contact to GP ^a	No	10,436	(78.0)	2936	(22.0)
	Yes	6760	(12.0)	49,476	(88.0)
Gender	Male	9617	(22.3)	33,160	(77.8)
	Female	7579	(28.7)	18,802	(71.3)
Age ^b (years)	30–49	456	(8.7)	4807	(91.3)
	50–59	1100	(11.5)	8446	(88.5)
	60–69	2588	(16.8)	12,865	(83.3)
	70–79	4363	(24.7)	13,333	(75.3)
	≥ 80	8689	(40.1)	12,961	(59.9)
Distance to nearest GP (km)	< 0.5	6012	(26.0)	17,073	(74.0)
	0.5–1.5	6746	(25.4)	19,856	(74.6)
	> 1.5	4438	(22.3)	15,483	(77.7)
Population to GP ratio ^c	< 1500	5013	(24.6)	15,396	(75.4)
	1500–2000	6847	(24.6)	21,020	(75.4)
	> 2000	5336	(25.0)	15,996	(75.0)

^a Contact to a general practitioner (GP) the year before acute myocardial infarction (AMI).

^b Age at AMI.

^c Population size per GP at municipality level.

status was obtained from the Danish Civil Registration System.

Information about contact to a GP the year before AMI was derived using the Danish National Health Service Register (Andersen et al., 2011). All contacts to the GP are registered in this register which is used for the GP's reimbursement for services. All types of contacts to a GP (i.e. consultations, home visits, e-mail and telephone consultations) were included. Contact to a GP within the year before date of the AMI was derived as a binary variable (yes, no).

The population to GP ratio at municipality level was calculated using the population distribution over the 98 municipalities in Denmark during first quarter of 2009, and a list of GPs with addresses from the Health Providers Register.

Information on the GP each individual is listed with is not available. Individuals with no contact to a GP the year before AMI cannot be related to a GP. Distance between the individual's residential location and the GP could only be calculated for the individuals with contact to a GP. As a measure for distance to GP the road network distance to

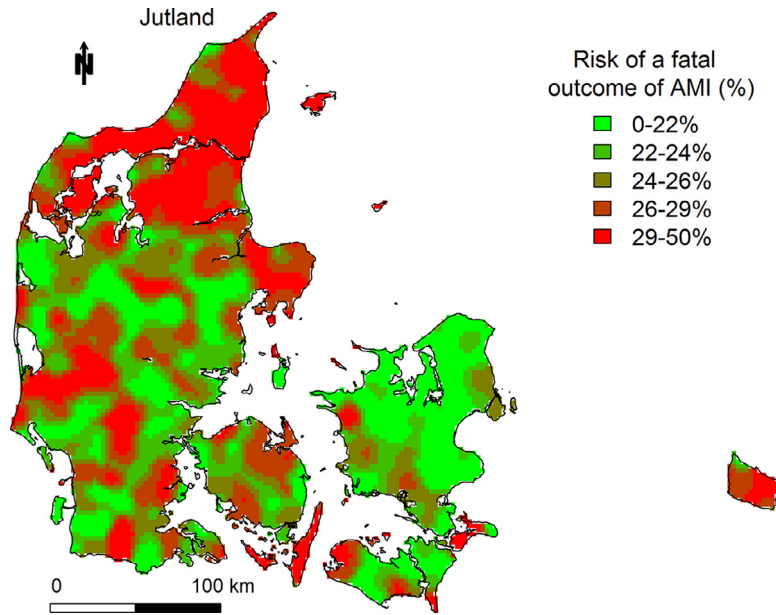


Fig. 1. Geographical distribution of the risk of a fatal outcome of acute myocardial infarction (AMI) in Denmark, 2006–2011. Risk of a fatal outcome of AMI is divided in 20% quintiles.

nearest GP was calculated for each individual although the nearest GP not necessarily was the GP the individual was listed with.

2.4. Geo-referenced data

Place of residence was obtained from the Danish Civil Registration System. Historic residential locations of the population were available from 1968 onwards. Standardized high quality geodata (i.e. UTM coordinates) were obtained for all addresses from a nationwide geographical address database established and maintained by the Danish Agency for Data Supply and Efficiency in cooperation with the Danish municipalities. Geocoding was not possible for 0.7% of the residential locations.

2.5. Kernel density estimation

The spatial distribution of a fatal outcome of AMI and of contact to a GP the year before AMI was derived using kernel density estimation (KDE). KDE was derived as the intensity function of the location of cases (i.e. fatal AMI or contact to a GP) divided by the intensity function of all locations of the study population at date of AMI. The estimate was calculated for grid cells of 2.5 km × 2.5 km using a non-parametric kernel estimator, a bandwidth of 5 km and the Gaussian kernel function.

2.6. Inverse distance weighting

The spatial distribution of distance to nearest GP was derived using inverse distance weighting (IDW) with 2.5 km × 2.5 km grid cells and a weighting function with the power parameter equal 2.

2.7. Statistical model

A Bayesian hierarchical logistic regression model including a spatially structured random effect was used to evaluate the association between contact to a GP and a fatal outcome of AMI, adjusted for differences in age and gender. The probability of a fatal outcome of AMI, π_i was modeled as:

$$\text{logit}(\pi_i) = \alpha + \sum_{p=1}^P \beta_p x_{pi} + W(s_i), \quad i = 1, \dots, N$$

where α is intercept, x_{pi} are covariates (contact to a GP, gender, age group, distance to nearest GP and population to GP ratio) and β_p are regression parameters. The spatially structured random effect $W(s_i)$ is a realization of a latent stationary GF modelling the spatial dependence between individuals at residential location, s_i . The spatially structured covariance matrix was modelled using the Matérn spatial covariance function $C(\Delta_{uv})$ (Cressie, 1993) depending on the Euclidean distance between the residential locations, $\Delta_{uv} = \|s_u - s_v\|$ where $u=1, \dots, N$ and $v=1, \dots, N$

$$C(\Delta_{uv}) = \frac{\sigma_w^2}{\Gamma(\lambda)2^{\lambda-1}} (\kappa \Delta_{uv})^\lambda K_\lambda(\kappa \Delta_{uv})$$

Here, $K_\lambda(\kappa \Delta_{uv})$ is the modified Bessel function of second kind and order λ . The smoothness parameter, λ was fixed at 1 and κ is a scaling parameter. Γ is the gamma function and σ_w^2 is the marginal variance. The range of influence, r (i.e. the distance at which the spatial correlation is close to 0.1) was defined as $r = \sqrt{8\lambda/\kappa}$ (Lindgren et al., 2011).

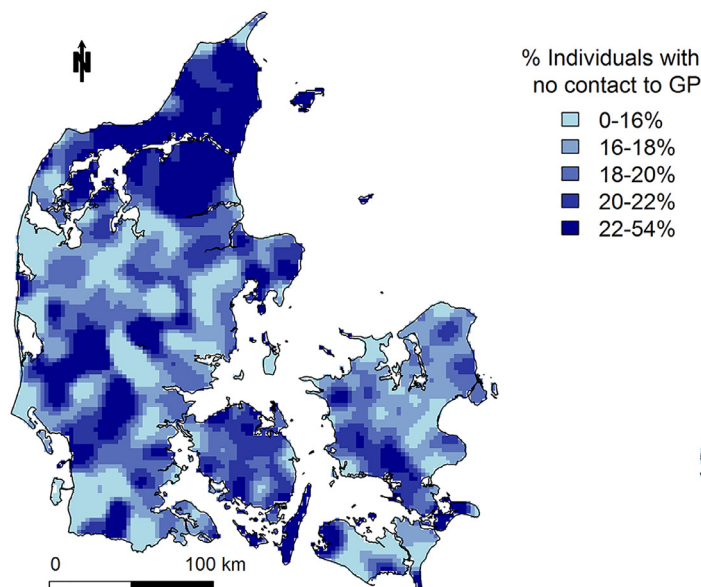


Fig. 2. Geographical distribution of the proportion of individuals with acute myocardial infarction (AMI) who did not have contact to a general practitioner (GP) the year before AMI in Denmark, 2006–2011. The proportion of individuals with no contact to a GP is divided in 20% quintiles.

2.8. Bayesian inference

Bayesian inference was performed using the Integrated Nested Laplace Approximation (INLA) approach (Rue et al., 2009) which is an efficient alternative to MCMC. The analysis was performed using R (R Core Team, 2013) and the INLA package (www.r-inla.org). The SPDE approach implemented in INLA was used to model the spatially structured covariance function (Lindgren et al., 2011).

Triangulation of the spatial region (referred to as the mesh) was based on the observed residential locations with additional mesh nodes to create a regular grid. To correct for potential edge effects the mesh was extended beyond the spatial region. The maximum triangle length was 5 km inside the spatial region and 50 km outside. The minimum distance between mesh nodes (i.e., the cut-off value) was 5 km. The mesh consisted of 2600 nodes (Supplementary material).

Model parameter estimates were based on mean, standard deviation and 95% credible intervals from the marginal posterior distributions. The odds ratio (OR) of fatal outcome of AMI and 95% confidence interval were calculated for the covariates (i.e., contact to a GP, age group,

gender, distance to nearest GP and population to GP ratio). Model fit and comparison between models were evaluated using the deviance information criteria (DIC) and the expected effective number of parameters (Spiegelhalter et al., 2002) with smaller values indicating a better fit. Residual spatial correlation was visually evaluated by mapping the estimated mean and standard deviation of the posterior GF.

To ease interpretation of the effect of contact to a GP the year before AMI, the OR was converted to a relative risk (RR). The RR of a fatal outcome of AMI for individuals with no contact to a GP the year before AMI compared to individuals with contact to a GP has been estimated based on the OR and the probability of a fatal outcome of AMI for individuals with contact to a GP the year before AMI (Zhang, 1998).

2.9. Prior distributions

Independent zero-mean Gaussian distributions with precision 0.001 were assigned to the regression parameters. The marginal variance σ_w^2 of the GF was parameterized as $\sigma_w^2 = 1/(4\pi\kappa^2\tau_w^2)$ (with π being the mathematical constant). The hyper parameters $\log(\kappa)$ and $\log(\tau_w)$ were

Table 2

Estimated odds ratio (OR) for a fatal outcome of an acute myocardial infarction (AMI) with 95% confidence intervals (95% CI) for three Bayesian hierarchical logistic regression models with a spatially structured covariance function in Denmark, 2006–2011.

Variable	Model I		Model II		Model III	
	OR	95% CI	OR	95% CI	OR	95% CI
Contact to GP						
No			40.32	38.0; 42.7	40.35	38.1; 42.8
Gender						
Male	0.96	0.93; 1.00	0.87	0.83; 0.91	0.87	0.83; 0.92
Age group (years) ^a						
50–59	1.37	1.22; 1.53	1.50	1.31; 1.72	1.50	1.31; 1.72
60–69	2.12	1.90; 2.35	2.99	2.63; 3.40	2.99	2.63; 3.40
70–79	3.41	3.08; 3.78	7.38	6.49; 8.35	7.35	6.47; 8.32
80+	6.92	6.26; 7.65	15.71	13.8; 17.8	15.56	12.7; 17.6
Population to GP ratio ^b						
1500–2000					0.98	0.91; 1.05
>2000					1.02	0.95; 1.09
Distance to nearest GP ^c						
0.5–1.5 km					1.01	0.95; 1.06
> 1.5 km					0.91	0.85; 0.97
	Estimates (SD or 95%CI)					
DIC ^d	72,533		49,318		49,314	
N _{parm} ^e	176.5 (33.9)		23.4 (4.2)		28.0 (4.3)	
Range, r ^f (km)	20.8 (13.1; 39.2)		243 (132; 977)		235 (129; 912)	
Marginal variance of GF ^g	0.044 (0.032; 0.072)		0.019 (0.009; 0.132)		0.0203 (0.009; 0.133)	

^a Age group 30–49 years as reference.

^b Population to GP ratio <1500 as reference.

^c Distance to nearest GP <0.5 km as reference.

^d Deviance information criteria.

^e Expected number of effective parameters.

^f Range of influence, r (km).

^g Posterior mode (95% CI).

assigned zero-mean Gaussian distributions with precision 0.1 (default of the INLA package).

2.10. Sensitivity analyses

A sensitivity analysis was performed to evaluate the effect of the mesh on the association between contact to a GP and a fatal outcome of AMI. The cut-off value was changed from 5 km to 2.5 km resulting in 8845 nodes.

Autopsy of the body after death for determination of the cause of death is not performed very often in Denmark. There could be a risk that the cause of death for older people is more uncertain than for younger people. To limit the risk of misclassification of the cause of death for older people, two sensitivity analyses were performed where the study population was limited to individuals with age ≤ 75 years and ≤ 65 years at AMI, respectively.

A sensitivity analysis was performed to assess the impact of the prior distributions by changing the precision from 0.1 to 0.001 and 0.00001 of the Gaussian distribution of the hyper parameters of the marginal variance of the GF.

3. Ethical considerations

The study was approved by the Danish Data Protection Agency (reference number 2012-41-1417). The present study was an observational study without direct contact to individuals and with no interventions of any kind.

4. Results

A total of 19.2% of the individuals had no contact to a GP the year before AMI (Table 1a). More individuals at age 80 years or older (23.8%) had no contact to a GP the year before AMI compared to younger individuals (Table 1a). Overall, 24.7% had a fatal outcome of AMI, 78.0% among individuals with no contact to GP the year before AMI and 12.0% among individuals with contact to a GP the year before AMI (Table 1b). The mean (SD) age at AMI was 70.9 (13.5) years for individuals with a non-fatal outcome of AMI and 73.4 (14.2) years for individuals with a fatal outcome of AMI. The geographical distribution of a fatal outcome of AMI showed large geographical differences (Fig. 1). Especially, the northern part of Jutland had a high proportion of a fatal outcome of AMI. The geographical distribution of contact to a GP showed large variation with a low percentage of the population with contact to a GP in northern Jutland, but also in other parts of the country (Fig. 2).

The Bayesian hierarchical logistic regression analysis of a fatal outcome of AMI included initially age and gender (Table 2, Model I). However, age and gender alone could not explain the elevated risk of a fatal outcome of AMI in northern Jutland as the geographical distribution of the mean posterior values of the GF indicates, showing large values in northern Jutland (Fig. 3, top left). The odds ratio (OR) of a fatal outcome of AMI among individuals with no

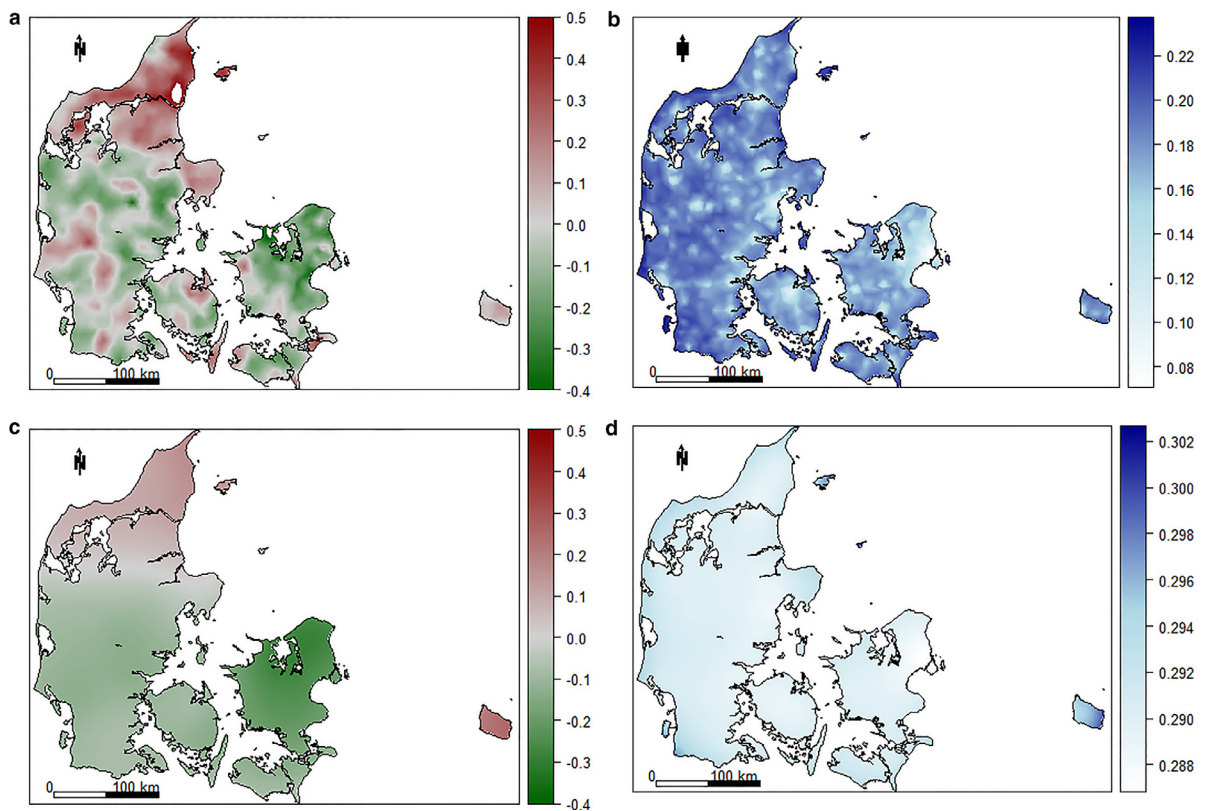


Fig. 3. Estimated Gaussian field (left) and standard deviation (right) illustrating residual spatial pattern in a fatal outcome of acute myocardial infarction (AMI) in Denmark, 2006–2011. Top: Model including age and gender (Model I, Table 2). Bottom: Model including contact to a general practitioner adjusted for differences in age and gender (Model II, Table 2).

contact to a GP the year before AMI was estimated at 40.3 (95% CI: 38.0; 42.7) (Table 2, Model II). The corresponding relative risk (RR) was 7.0 (95% CI: 6.9; 7.1). Lack of contacts to a GP could explain the majority of the high proportion of a fatal outcome of AMI, resulting in very little residual spatial correlation indicated by the geographical distribution of the mean posterior values of GF (Fig. 3, bottom left). The effect of contact to a GP is also seen in the reduction of the DIC and expected number of effective parameters when including contact to a GP in the model (DIC changed from 72,533 in Model I to 49,318 in Model II, Table 2). Analysis of Model II without the spatially structured covariance function (i.e. a standard logistic regression analysis) resulted in a DIC of 49,428 indicating that the spatial component modeled by the GF is significant (data not shown). Contact to a GP the year before AMI accounted for the majority of the spatial variation in a fatal outcome of AMI. However, residual spatial correlation is still present.

The population to GP ratio within municipalities showed some overlap with areas with a low percentage of the population having contact to a GP and with areas with a high proportion of a fatal outcome of AMI (Fig. 4). The distance to nearest GP showed long distance to GPs in some of the areas with a high proportion of a fatal outcome of AMI (Fig. 5). However, the variables

were only weakly associated with a fatal outcome of AMI (DIC decreased by 4 in model III compared to model II, Table 2).

The sensitivity analysis of the effect of the selected mesh showed that changing the mesh cut-off value did not impact the association between contact to a GP and a fatal outcome of AMI (OR = 40.3, 95%CI: 38.0; 42.7). Limiting the study population to individuals with age ≤ 75 years and ≤ 65 years at date of AMI resulted in a slightly weaker association between contact to a GP and a fatal outcome of AMI (OR = 30.8, 95%CI: 28.7; 33.2 and OR = 27.3, 95%CI: 24.6; 30.2). Finally, changing the prior distributions of the hyper parameters of the marginal variance of the GF resulted in the same association between contact to a GP and a fatal outcome of AMI (OR = 40.3, 95%CI: 38.0; 42.7) and no visual effect on the estimated GF (not shown).

5. Discussion

An uneven geographical distribution of a fatal outcome of AMI was observed and it was significantly associated with contact to a GP the year before AMI. Individuals with no contact to a GP had 40 times higher odds (corresponding to seven times higher risk) for a fatal outcome of AMI compared to individuals with no contact to a GP the year before AMI. A total of 19.2% of the individuals had no

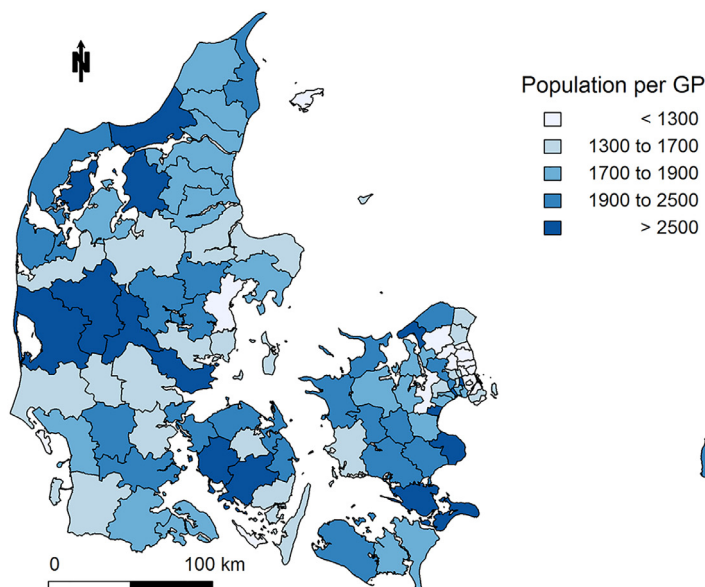


Fig. 4. Geographical distribution of the population to general practitioner (GP) ratio in municipalities in Denmark, first quarter 2009 based on total population in Denmark.

contact to a GP the year before AMI. The geographical distribution of contact to a GP the year before AMI was uneven with a high proportion of individuals with no contact to a GP in areas with a high proportion of a fatal outcome of AMI. Among individuals with no contact to a GP the year before AMI, 78% had a fatal outcome of AMI compared to a fatal outcome for 12% of the individuals who had contact to a GP the year before AMI. The reasons for the low percentage of contact to a GP in certain areas are unknown. One reason could be a limited number of GPs in the area (i.e. a high population to GP ratio). It could also be due to longer distances to GPs in certain areas. However, a high population to GP ratio and long distance to GP could not explain the increased odds of a fatal outcome of AMI for individuals with no contact to a GP in the present study. Therefore, other barriers for contact to a GP should be considered. The GPs act as gatekeepers and are the first point in contact to health services. The interaction between the patient and GP has been suggested as a key element in the use of health services (Arber et al., 2006; Lang et al., 2005). The patient and GP may have different socio-economic positions and this social distance between the patient and GP could also have an effect on communication (Lang et al., 2012).

Strengths of the study include access to the entire Danish population of individuals with AMI through administrative health registers. This limits the risk of selection bias introduced when using survey data. Access to and use of exact residential location of the population is a huge advantage as it excludes the risk of bias introduced when data are aggregated in polygons using administrative boundaries. This problem is known as the modifiable areal unit problem (Openshaw and Taylor, 1979) and can be disregarded as a potential bias in the present study. Furthermore, it was possible to geocode more than 99% of the current and historic addresses of the study population. Finally, the validity of the AMI diagnosis in the National Patient Register and the Danish Register of Causes of Death is considered high (Madsen et al., 2003).

Limitations include the lack of validation of the Danish National Health Service Register. However, it is assumed that the coverage of registration is high as registration is based on a fee for service remuneration to the GP (Andersen et al., 2011). Information on the GP each individual is listed with is not available. Individuals with no contact to a GP the year before AMI cannot be related to a GP. Therefore, proxy variables were used for distance to the GP and the population to GP ratio.

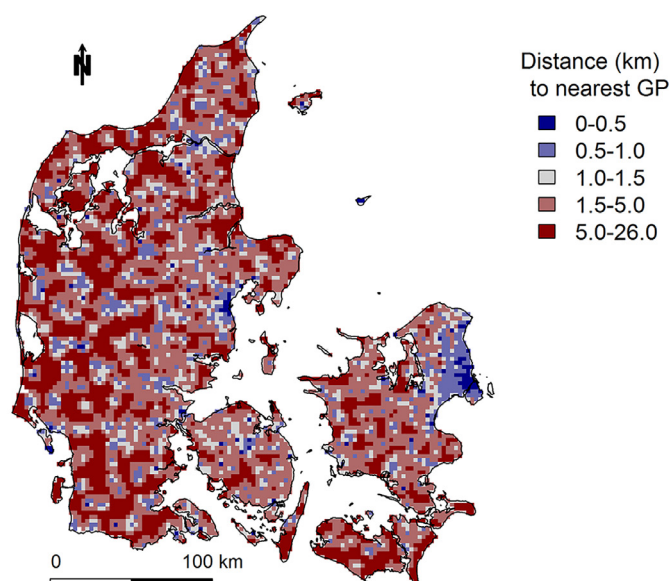


Fig. 5. Geographical distribution of the road network distance to the nearest general practitioner (GP).

6. Conclusion

Geographical variation in a fatal outcome of AMI and contact to a GP the year before AMI was seen. Contact to a GP accounted for the majority of the spatial variation in a fatal outcome of AMI. The study showed that contact to a GP had a significant effect on the risk of a fatal outcome of AMI. Individuals with no contact to a GP the year before AMI had 40.3 times higher odds (corresponding to a seven times higher risk) of a fatal outcome of AMI compared to individuals with contact to a GP the year before AMI. However, the lack of contact to a GP could not be explained by a large population to GP ratio or long distance to nearest GP. Further studies are needed to examine reasons for lack of contact to a GP in this population.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.sste.2016.06.001](https://doi.org/10.1016/j.sste.2016.06.001).

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